Rymer, Edwina

From: Dorsey, Nancy
Sent: Monday, June 22, 2015 8:36 AM
To: Tim Baker;Matt Skinner;Charles Lord;Patricia Downey
Cc: Dellinger, Philip
Subject: FW: two NEW postings a IS
Attachments: Weingarten et al Science with Supplemental.pdf; Walsh and Zoback Science Advances Final.pdf

(Colors added)

MANAGING INJECTION-RELATED SEISMIC RISKS – from Walsh and Zoback
Injection of large volumes of saltwater into the Arbuckle group appears to be triggering the release of already stored strain energy in crystalline basement. It would seem logical that reducing the volume of injected saltwater into the Arbuckle should reduce the amount of triggered seismicity. In addition, as shown by the areas with many EOR wells recycling produced water in producing horizons, reinjection of the saltwater into the horizons that produced the water and oil would not be expected to trigger seismicity. Thus, the feasibility of injecting the large volumes of produced water back into depleted portions of the producing reservoirs needs to be investigated.

In a recent study of the Jones earthquakes (30), it was argued that four large-scale injectors (two of which were injecting more than 1 million barrels/month) located just southeast of Oklahoma City are the principal cause of the Jones seismicity, much of which is located over 10 km from the injectors. In the three study areas where SWD injection and seismicity have increased, the few SWD wells injecting unusually large volumes (for example, more than 400,000 barrels/month) contribute a relatively small fraction of the total SWD volume in those areas (21% in Cherokee, 19% in Perry, and 45% in Jones; see fig. S2). Thus, whereas reducing the cumulative volume of SWD should be beneficial, establishing an arbitrary upper limit to injection rates of any single well may not reduce the probability of triggering seismicity if the same volume was to be injected in a number of lower-rate wells nearby.

Without detailed modeling, it is difficult to predict how restricting or more broadly distributing the injection volumes in the study areas would affect seismicity. It is likely that even if injection from many wells were to stop immediately, seismicity would continue as pressure continues to spread out from past injection. Over time, of

course, one would expect seismicity to diminish if the aggregate rate of injection in the seismically active areas were to significantly decrease. As the seismicity rate in Oklahoma a decade ago was similar to the historical rate, there may be some rate of injection that can be accommodated by the regional hydrologic system without generating the pressure increases responsible for seismicity.
To date, there have been two published modeling studies relevant to Oklahoma seismicity (24, 30). In both, it was argued that small pressure perturbations could propagate laterally within the disposal zone for 10 km or more, before triggering slip on critically stressed faults in the basement. However, with little constraint of subsurface hydrologic properties such as porosity, permeability, and pore pressure (and its variations with time), it is difficult to use models to make reliable predictions. A concerted effort of systematic data collection is needed to better constrain hydrologic models to devise strategies for modifying injection practices to reduce the probability of triggered seismicity.

It would be helpful to evaluate if there is stratigraphic control on the tendency for SWD into particular wells or zones to trigger seismicity. The importance of a bottom-sealing layer to prevent pressurization of basement faults has been pointed out in a generic modeling study (24). Injection into aquifers that are physically separated from crystalline basement by relatively impermeable formations would be beneficial as would avoiding pressurization near potentially active faults (2). Combining subsurface fault data with information about the stress field permits identification of which faults are critically stressed and to be avoided.

It has been suggested that the largest earthquake in an area correlates with the total injected volume in the area (27). However, in the context of triggered seismicity, the largest earthquake that might be triggered is determined by preexisting geologic conditions, not the magnitude of the perturbation of pore pressure. It is also clear that greatly improved earthquake monitoring and real-time analysis would be helpful to assess changes in seismic hazard with time. Determination of accurate earthquake locations (especially earthquake depth) requires relatively dense seismic networks. Real-time analysis of earthquake locations and the style of faulting can be used to identify potentially hazardous situations, such as earthquakes aligning along basement faults that could be large enough to cause a potentially damaging earthquake.

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Cc: Mike Paque; Dan Yates; Gerry Baker; Leslie Savage; Matt Kellogg
Subject: RE: two NEW postings a IS

See reports attached and at…
http://www.gwpc.org/resources/induced-seismicity-resources

THANKS!
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